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RESEARCH MEMORANDUM

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DRAG MEASUREMENTS OF A SWEEPED-BACK WING HAVING INVERSE TAPER
AS DETERMINED BY FLIGHT TESTS AT SUPERSONIC SPEEDS

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RESEARCH MEMORANDUM

DRAG MEASUREMENTS OF A SWEEP-BACK WING HAVING INVERSE TAPER
AS DETERMINED BY FLIGHT TESTS AT SUPERSONIC SPEEDS

By Sidney R. Alexander

SUMMARY

Results of flight tests conducted at the test station of the Langley Pilotless Aircraft Research Division at Wallops Island, Va. to determine the drag at zero lift of a swept-back wing of inverse taper are presented. The wing had an aspect ratio of 3.0, taper ratio of 1.62, and leading-edge sweep of 35° . The airfoil was of NACA 65-009 section taken normal to the leading edge. The data were obtained by radar tracking of the rocket-propelled winged body moving at supersonic speeds. A comparison is made with the results of similar tests of untapered wings having 34° and 45° sweepback of a previous paper, NACA RM No. L6J16. The test results showed that for the comparable Mach number range investigated ($M = 1.0$ to 1.275) the tapered wing produced values of drag coefficient that averaged about 30 percent lower than those of the 34° swept-back untapered wing and about 20 percent higher than those of the 45° swept-back untapered wing. At Mach numbers of 1.1 and 1.2, the tapered wing revealed drag coefficients of 0.0195 and 0.0225, the latter value being the maximum value obtained for this arrangement.

INTRODUCTION

The Langley Pilotless Aircraft Research Division has included in its high-speed drag research program, tests of a swept-back wing having inverse taper (tip chord greater than root chord). It was reasoned that if sweepback and taper both produce wing-tip stall, then the use of inverse taper would tend to promote center-section stall and counteract, to some extent, the inherently poor stalling characteristics of the swept-back wing.

This paper presents the results of flight tests conducted at supersonic speeds to determine the drag at zero lift of a swept-back wing of inverse taper mounted on a rocket-propelled body.

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BODY AND TESTS

Body

The rocket-propelled winged test body was constructed of wood and was about 5 feet long and 5 inches in diameter. A photograph of the test body equipped with the swept-back inverse-taper wing is presented as figure 1. The wing was mounted on the body at zero incidence with the mean quarter-chord point at the same longitudinal station as the design center of gravity. The NACA 65-009 airfoil section (chord normal to leading edge) had neither twist nor dihedral. The sweepback of the leading edge $\Lambda_{l.e.}$ was 35° and that of the quarter-chord line was 37.5° . The aspect ratio A , including that part of the wing enclosed by the body, was 3.0, and the taper ratio c_t/c_r (ratio of tip chord to root chord) was 1.62.

The fuselage consisted of a sharp nose fitted to a hollow cylindrical afterbody around which four stabilizing fins were equally spaced, each fin comprising a flat surface with rounded leading edges swept back 45° and trailing edges cut off square. The fins were indexed 45° to the wing. Details of the general arrangement are shown as figure 2.

The test body was propelled by a 3.25-inch diameter Mk.7 aircraft rocket motor enclosed within the body. At a preignition temperature of 69°F , the motor provided about 2200 pounds of thrust for approximately 0.87 second.

Tests

The testing technique involved consists of launching the body at an elevation angle of 75° to the horizontal. Because of this high angle and the short burning duration of the rocket motor, the trajectory during the supersonic coasting flight, after the propellant was expended, was approximately a straight line. The flight velocity was measured by means of a CW Doppler radar set (AN/TPS-5) located at the point of launching. The values of temperature and static pressure used in calculating drag coefficients and Mach number were obtained from radiosonde observations made at the time of firing.

RESULTS AND DISCUSSION

The variation of velocity with flight time for the test body, as measured with the radar unit, is presented in figure 3. The maximum velocity reached by the body was 1495 feet per second, which corresponds to a Mach number of about 1.32. The portion of the velocity curve during which coasting flight was attained (after the propellant had been expended) was graphically differentiated to obtain the deceleration. From this value and the known mass of the body, the drag was obtained. This is presented in figure 4 plotted against Mach number M . Although the scatter of the velocity-time curve has been greatly magnified by its differentiation, the drag curve is satisfactorily determined. Drag coefficients calculated for the test body from the data of figure 4 and based on an exposed wing area of 200 square inches are presented in the upper part of figure 5. As a means of estimating the relative effectiveness of the tapered wing, similar curves for the test bodies of reference 1 with the NACA 65-009 rectangular airfoils of 34° and 45° sweepback and aspect ratio 2.7 are included, as well as the data for a wingless body arrangement. This latter curve has been modified slightly from the corresponding one of reference 1 to include the average results of three more identical wingless test bodies since fired. It should be pointed out that the low Mach number range in these tests is reached when the test body is farthest from the launching site. In this region, the strength of the radar signal and the character of the drag variation make inherently difficult a precise determination of the drag at a given Mach number. Because of the steepness of the drag-coefficient curve against Mach number, a very small error in Mach number determination will cause a large percentage error in the drag coefficient. Examination of the drag-coefficient curves of similar test bodies (in the Mach number range between 0.85 and 1.0) reveal displacement and/or changes in slope of the drag-coefficient curves that result in discrepancies in drag coefficient at a given Mach number as high as ± 10 percent compared with ± 3 percent in the region above a Mach number of 1.0. The accuracy has since been increased by obtaining more accurate temperature-pressure-altitude soundings, but for any appreciable increase in accuracy for Mach numbers below 1.0, slower models should be used.

It should be remembered also that in the transonic speed range peculiar transfers of drag take place between the wing and the body so that wing drag plus its interference may vary greatly for different designs. For the same reason, a change in the body shape on which the wings are mounted may also change the drag due to the wings.

Corresponding curves of wing drag coefficient derived by taking the difference between the total-drag-coefficient curves of the winged and wingless test bodies are presented in the lower portion of figure 5. These values include wing-fuselage interference effects. For the range of comparable Mach numbers, the tapered wing had values of drag coefficient that averaged about 30 percent lower than those of the 34° swept-back untapered wing and about 20 percent higher than those of the 45° swept-back untapered wing. At Mach numbers of 1.1 and 1.2, the tapered wing produced drag-coefficient values of 0.0195 and 0.0225, this latter value being the maximum value obtained for this arrangement. Inasmuch as the difference in aspect ratio and leading-edge sweep angle between the wing having inverse taper and the 34° swept-back rectangular airfoil is small, the reduction in drag coefficient of the tapered wing over the untapered one can be attributed to a combination of the following effects: wing-fuselage interference, percentage of wing area located in the region of high pressure drag near the wing root, or the possibility of the sweep of some percent chord line other than the leading edge controlling the action of the drag as is theoretically indicated in reference 2 for the case of "delta" wings. The relative contributions of each to the over-all drag value could be determined only by further tests of tapered wings.

CONCLUDING REMARKS

Flight tests to determine the drag of a swept-back wing having inverse taper were conducted by the Langley Pilotless Aircraft Research Division at Wallops Island, Va. The wing had an aspect ratio of 3.0, taper ratio of 1.62, and leading-edge sweepback of 35° . The drag coefficients of two untapered wings of aspect ratio 2.7 and sweepback angles of 34° and 45° obtained in an identical fashion have also been included as a means of comparison. The results showed that for the comparable Mach number range investigated ($M = 1.0$ to 1.275) the tapered wing had values of drag coefficient that averaged about 30 percent lower than those of the 34° swept-back untapered wing and about 20 percent higher than those of the 45° swept-back untapered wing. At Mach numbers of 1.1 and 1.2 the tapered wing produced drag-coefficient values of 0.0195 and 0.0225, this latter value being the maximum value obtained for this arrangement.

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REFERENCES

1. Alexander, Sidney R., and Katz, Ellis: Drag Characteristics of Rectangular and Swept-Back NACA 65-009 Airfoils Having Aspect Ratios of 1.5 and 2.7 as Determined by Flight Tests at Supersonic Speeds. NACA RM No. L6J16, 1946.
2. Puckett, Allen E.: Supersonic Wave Drag of Thin Airfoils. Jour. Aero. Sci., vol. 13, no. 9, Sept. 1946, pp. 475-484.

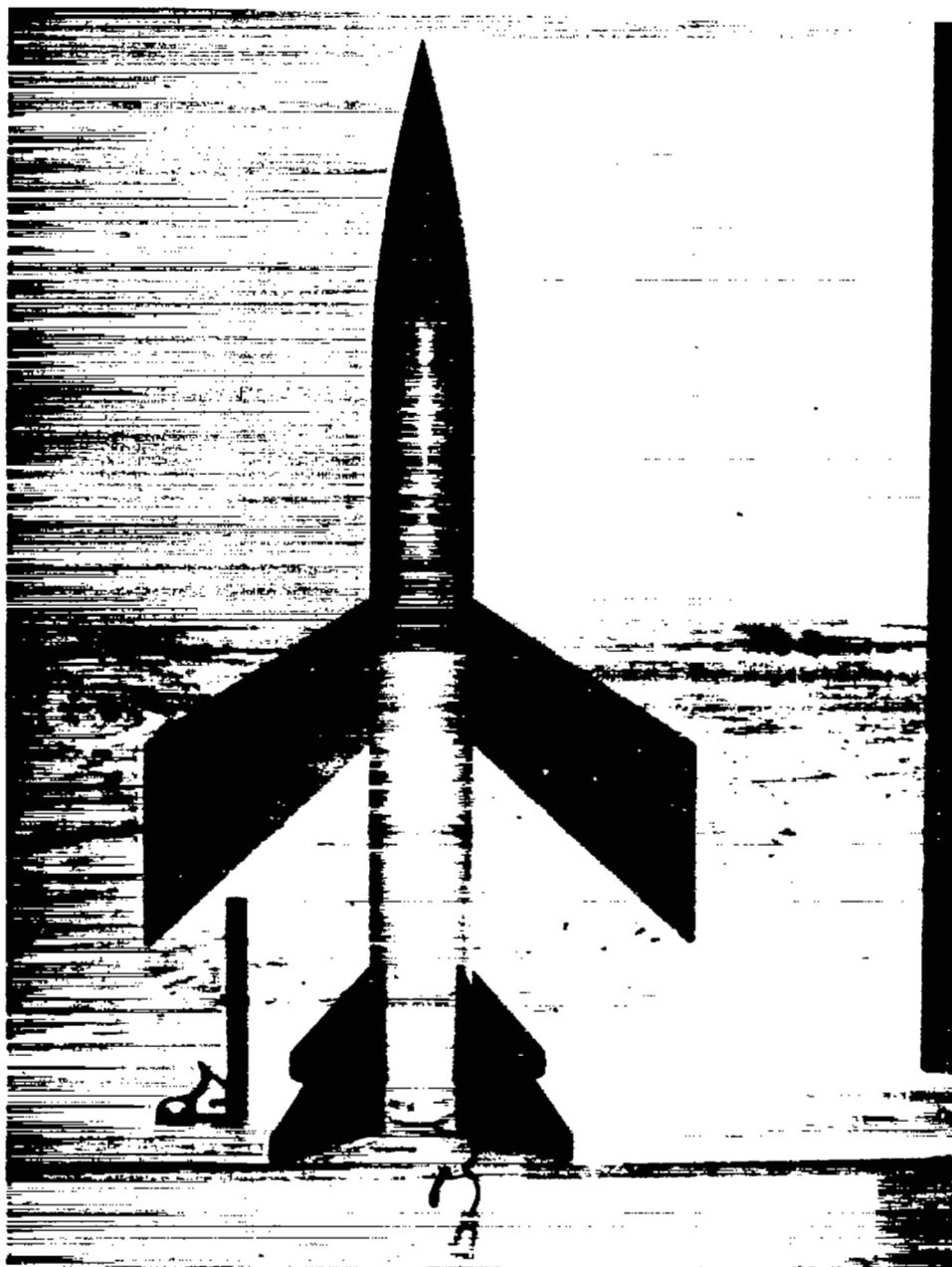


Figure 1.- The test body with swept-back wing having inverse taper.

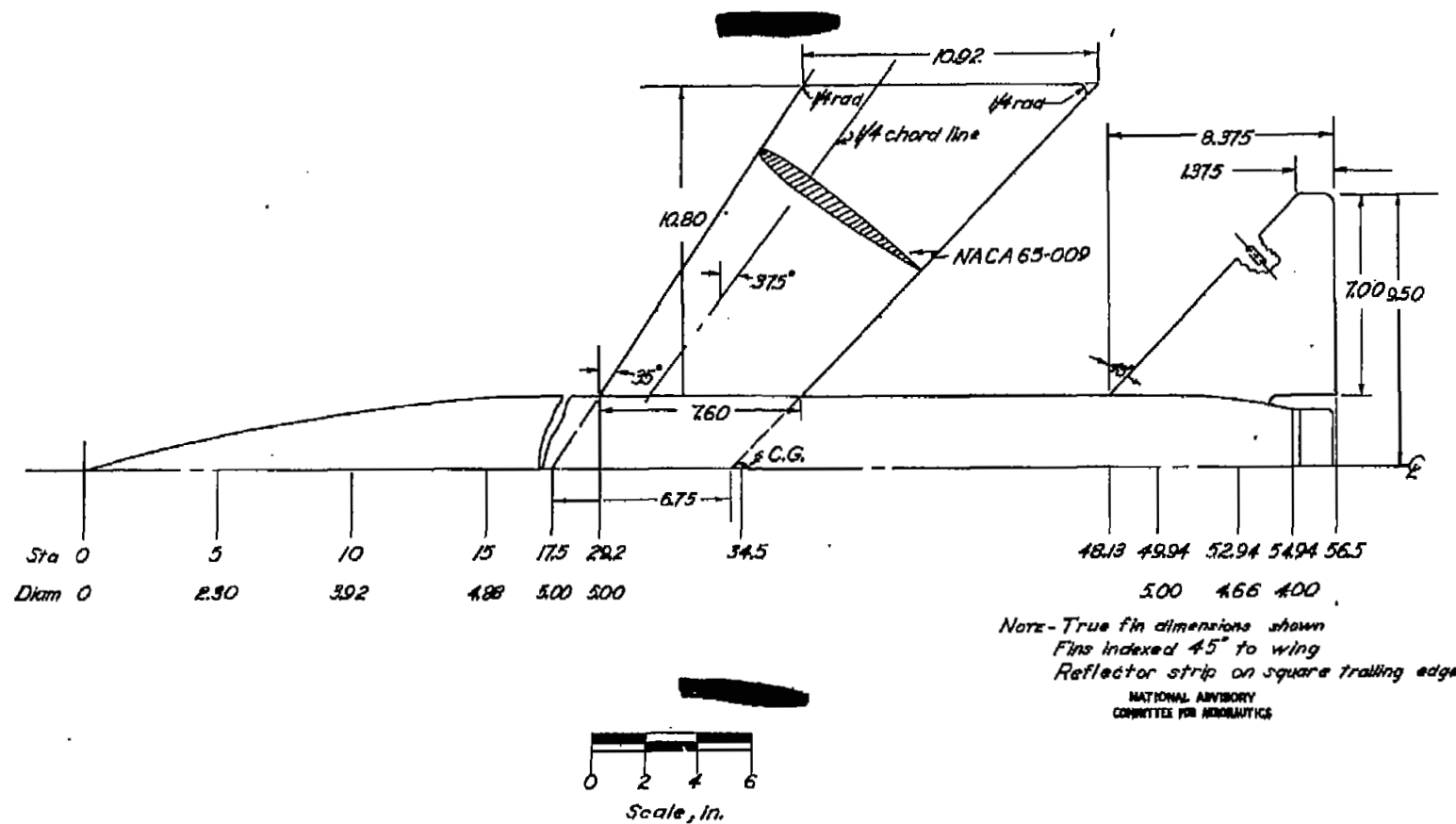


Figure 2- General arrangement of test body with inverse taper wing of aspect ratio 3, taper ratio 1.62

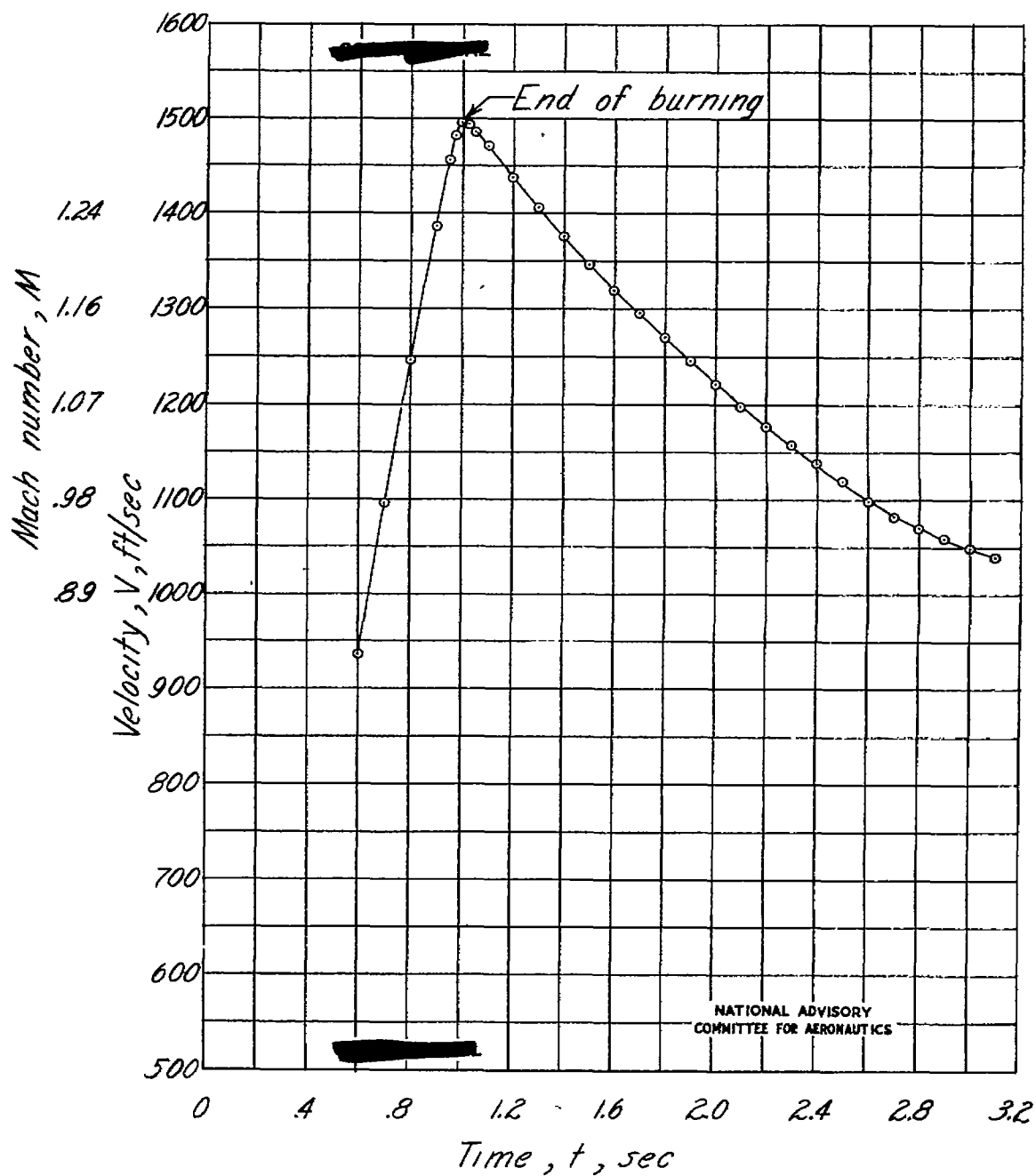


Figure 3.- Velocity-time curve. Test body with swept-back wing having inverse taper. $A = 3.0$; $\Lambda_{LE} = 35^\circ$.

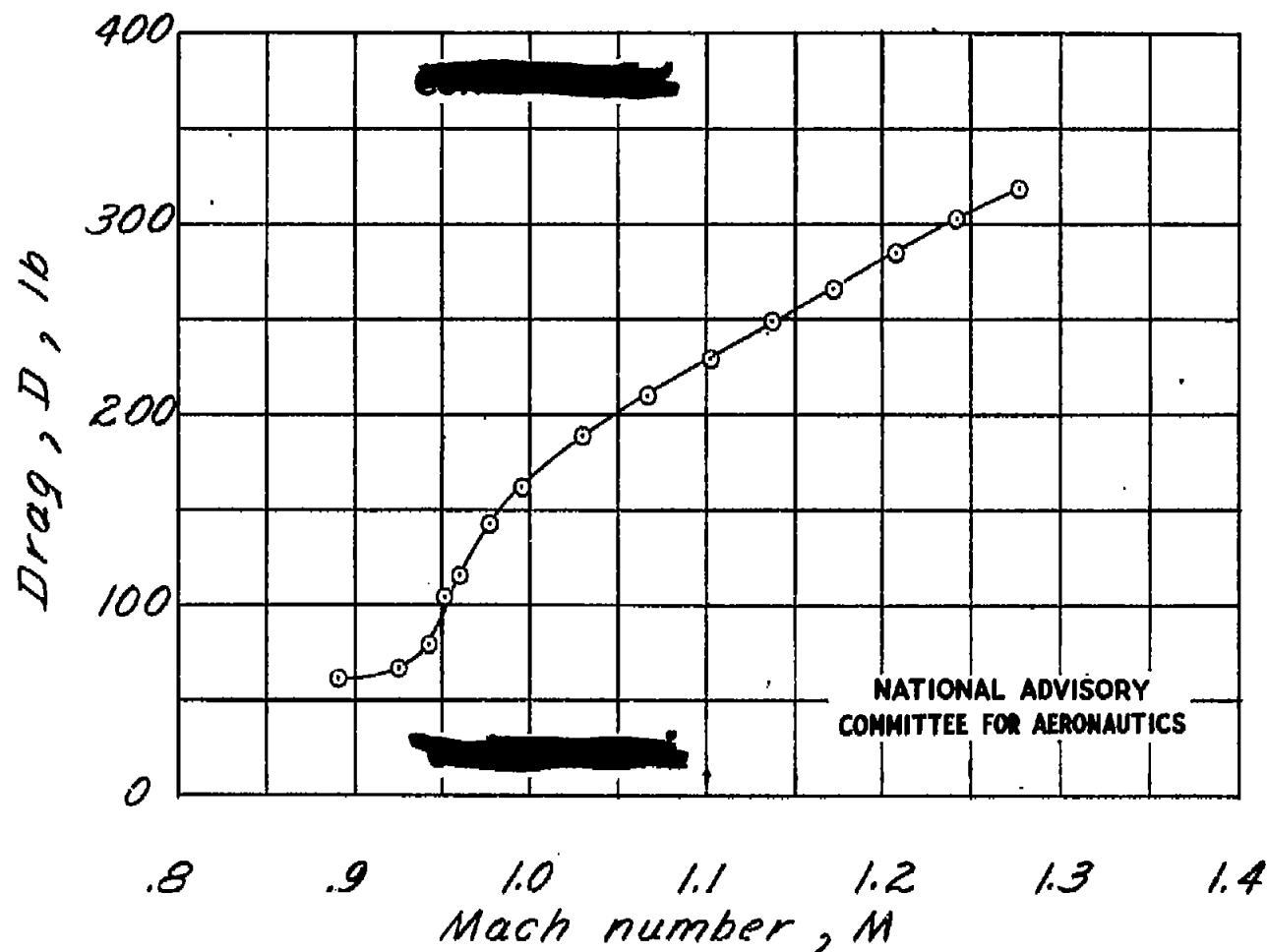


Figure 4.-Total drag of test body with swept-back wing having inverse taper.
 $A = 3.0$; $\Lambda_{L.E.} = 35^\circ$.

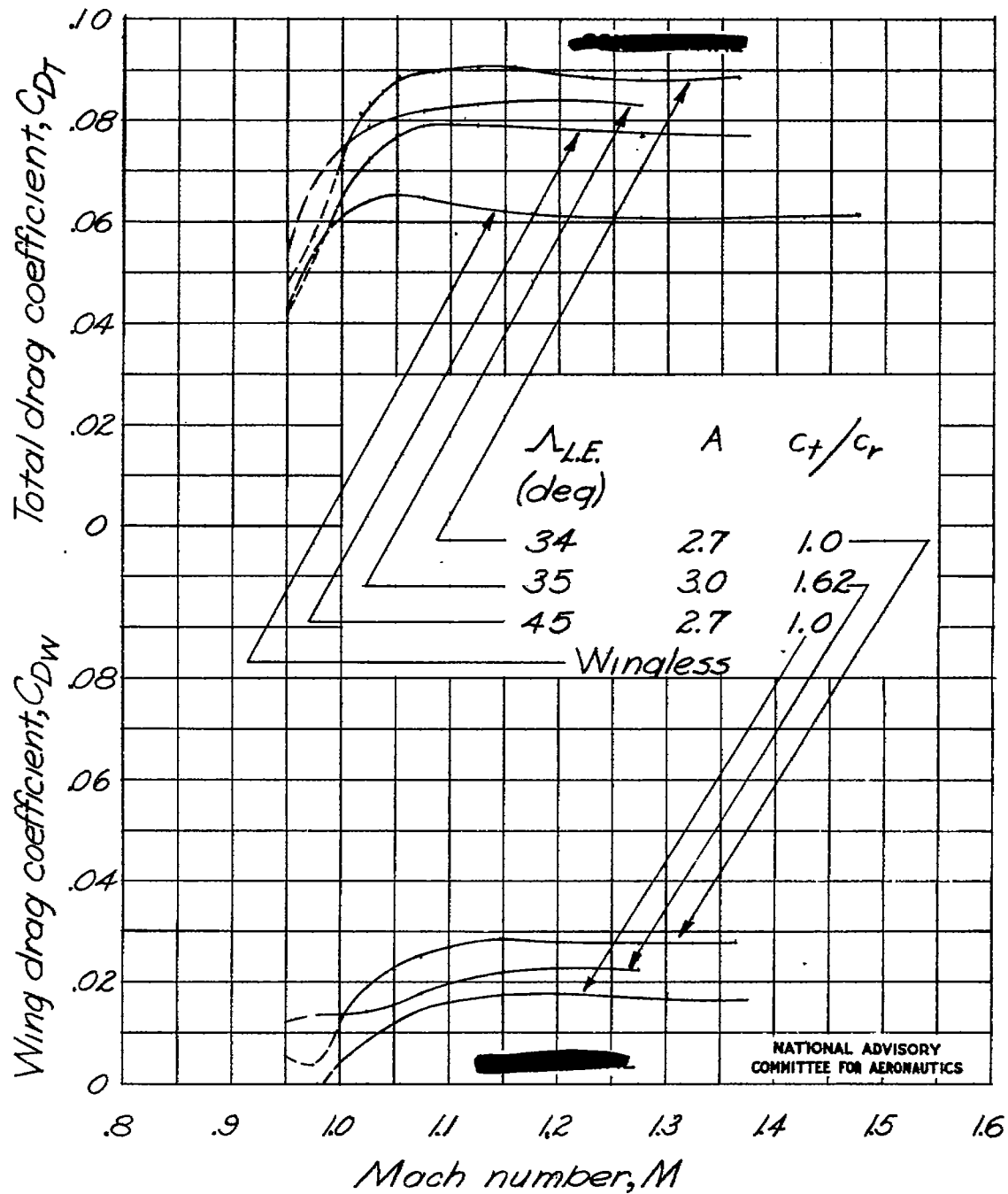


Figure 5.- Comparison of drag-coefficient data for a swept-back wing having inverse taper and two swept-back untapered wings.

